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Aggregate Resources Inventory of the Township of Wainfleet

Regional Municipality of Niagara
Southern Ontario

By Staff of the Engineering and Terrain Geology Section, Ontario Geological Survey

1985

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Aggregate Resources Inventory of the Township of Wainfleet Regional Municipality of Niagara

by
Staff[1] of the Engineering and Terrain Geology Section

1. Project supervisor: Dale W. Scott; field work and report by G. Jones; compilation and drafting by staff of the Aggregate Assessment Office. The Mineral Resources Staff of Niagara District and Central Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

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Abstract

This report includes both an inventory and evaluation of sand and gravel, as well as bedrock resources, in the Township of Wainfleet. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under the Pits and Quarries Control Act.

The Township of Wainfleet has limited granular resources. The existing deposits have limited thickness and areal extent, however, a number have been selected at the secondary level of significance. These deposits may be capable of supplying small amounts of low-specification construction aggregate for local use. Care should be taken to ensure the continuing availability of as much of the remaining resources as possible.

Presently, the Township of Wainfleet relies on bedrock-derived aggregate and imported sand and gravel to meet most of its aggregate needs. The township is underlain by bedrock of the Salina, Bertie, Bois Blanc and Onondaga Formations. Of these, the Bertie, and to a lesser extent, the Bois Blanc and Onondaga Formations are suited for extractive development. Three areas have been selected for possible resource protection. An estimated 2600 acres (1050 ha) are currently available for extraction, containing possible resources of 510 million tons (465 million tonnes).

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

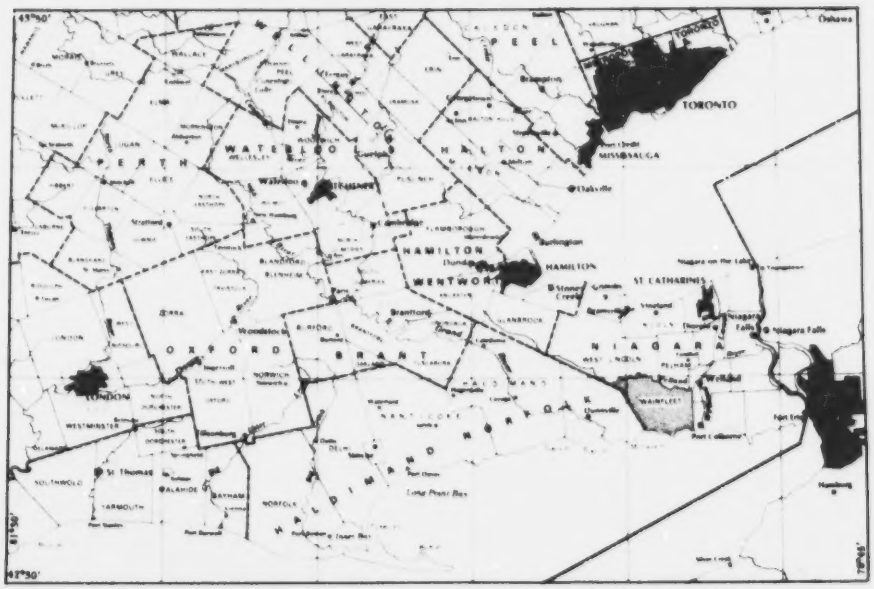


Figure 1. Key Map Showing the Location of the Township of Wainfleet, Scale 1:1 800 000.

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1982, the total tonnage of mineral aggregates extracted was 101 million tons (92 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1983).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing, hand augering and geophysical techniques are used to assess subsurface materials. Airphotos at various scales are used to determine the continuity of deposits, especially in areas where information is limited.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100-pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution and in some cases Los Angeles abrasion, absorption, and Magnesium Sulphate soundness tests along with petrographic analyses are performed.

Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey. In areas of limited subsurface exposure, test holes are drilled and geophysical surveys using hammer seismic equipment are undertaken. The symbols for and locations of sample and test hole sites along with geophysical traverse lines are noted on Map 1.

In the office, the field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records. The

measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one-foot (0. 3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

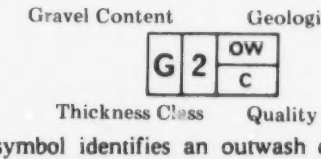
Map 1 is derived from existing surficial geology maps of the area or from airphoto interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, all sand and gravel deposits are outlined and shaded. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken for analysis during field study. The information from which these symbols are derived has been plotted in grain size distribution graphs. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

Test hole locations are shown on Map 1 by a solid drill hole symbol. Geophysics lines are shown on the map by a line symbol.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Al-

though deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quanitities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single, land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6 m), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the litholgy of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Analyses of unprocessed samples obtained from test holes, pits or sample sites have been plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course A, B and C; Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on ex-

tractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalites with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three levels of shading. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas consitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource ares. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected drill hole which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approch. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Part III — Assessment of Aggregate Resources in the Township of Wainfleet

LOCATION AND POPULATION

The Township of Wainfleet occupies an area of 53,143 acres (21 507 ha) in the southwestern part of the Regional Municipality of Niagara. The township is shown on parts of the Dunnville (30 L/13), Hamilton- Grimsby (30 M/4), Niagara (30 M/3) and Welland (30 L/14) map sheets of the National Topographic System at a scale of 1:50 000. The township is bordered by the Welland River on the north and Lake Erie on the south.

The population of the township was 6020 in 1982, an increase of approximately 9 percent since 1972 (Ontario Ministry of Municipal Affairs and Housing 1983; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). The majority of the residents in the township are engaged in farming or are rural-residential inhabitants. There is also a large recreational population along the shore of Lake Erie.

Access within the township is provided by King's Highway 3 as well as gravel-surfaced and paved township roads, and paved regional roads. The township is also served by lines of the Canadian National, Conrail, and Toronto, Hamilton and Buffalo Railways. Transportation by ship is provided by the Welland Canal which runs through Port Colborne, just to the east of the township.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography and distribution of unconsolidated sediments, including sand and gravel deposits, are predominantly the result of glacial activity which took place during the Late Wisconsinan Substage of the Pleistocene Epoch, informally known as the 'Great Ice Age'. This substage, which lasted from approximately 23 000 to 10 000 years ago, was marked by the repeated advance and melting back of massive, continental ice sheets.

The Township of Wainfleet is included in the physiographic region referred to as the Haldimand Clay Plain (Chapman and Putnam 1966). In the Niagara Peninsula, the plain slopes gently southward from the Niagara Escarpment to Lake Erie and consists of glaciolacustrine clay and silt. The clay and silt were deposited in the deep waters of proglacial lakes which covered the area as the glacial ice retreated. In the Township of Wainfleet, older till deposits are extensively overlain by the younger glaciolacustrine sediments, with the exception of two small till exposures north of Burnaby. These exposures are part of the buried Wainfleet Moraine which was probably formed during a temporary halt of the retreating ice (Feenstra 1981). Both the glaciolacustrine deep water sediments and till have little value as aggregate, because of their high silt and clay content.

As the water level in the proglacial lakes lowered, an increasing amount of land was exposed in the west (Feenstra 1981). An ancestral Grand River flowed into the shallow western part of the water body near the community of Dunnville (west of the township). Fine to silty fine sand was carried by the river and deposited in the shallow waters of this lake, forming a broad delta along the western boundary of the township. Nearshore features such as beaches and bars were also deposited during the subsequent lowering of water levels. Several small nearshore deposits are located north of Grabell Point and Morgans Point in the south-central part of the town. They consist of gravelly sand and fine gravel and are situated on till ridges or bedrock rises (Feenstra 1981).

After the waters in the lakes drained, the deltaic sand became susceptible to postglacial wind erosion and transport. Deposition of eolian sand occurred mainly in the form of parabolic dunes (Feenstra 1981). No pits have been developed in these dunes in the township, but similar deposits have been utilized for aggregate to the west in the Town of Dunnville.

The deposition of alluvium along the banks of the Welland River and its tributaries as well as the recent development of beaches and dunes along Lake Erie, and the formation of the Wainfleet Marsh, are also features of the physiography of the area. The Wainfleet Marsh is an extensive peat deposit situated along the township's eastern boundary. Peat is extracted from the marsh for use as soil conditioner (Feenstra 1981).

EXTRACTIVE ACTIVITY

One unlicenced sand pit and two quarries have been developed in the Township of Wainfleet. At the time of writing, one quarry was licenced to operate and had a licenced area of 253.0 acres (102.4 ha). The township was designated in 1974 under the Pits and Quarries Control Act.

Since the Township of Wainfleet has a limited supply of quality sand and gravel, bedrock-derived aggregate and imported sand and gravel are required to meet most of its needs. However, the township does have several sources of sand and gravel which may be capable of meeting some of the local demands for low-specification construction products. Care should be taken to ensure the continuing availability of as much of the remaining resources as possible.

SELECTED SAND AND GRAVEL RESOURCE AREAS

A number of sand and gravel deposits have been selected for possible resource protection at the secondary level of significance. Since information pertaining to the quality of sand and gravel in the township is lacking and the deposits have limited thickness and areal extent, no deposits have been selected at the primary level of significance.

A beach deposit located in the south-central part of the township consists predominantly of coarse sand and fine gravel and may be capable of supplying small quantities of aggregate for local use. Although information concerning the quality of the aggregate in this deposit is lacking, the material may be similar to that exposed in a small excavation in a beach deposit south of Burnaby. The material was sampled by Feenstra (1981) and found to contain 55 percent gravel (WF-SS-2, Figure 2). Gradation analysis performed on the unprocessed aggregate indicated that it may be suitable for some granular base course products.

A number of the larger sand dunes situated along the western boundary of the township consist of uniform, fine-grained sand. Although no pits have been developed in these deposits, information obtained from pits in similar deposits to the west in the Town of Dunnville, indicates some low-specification construction products including fill, Granular Base Course C and blending sand may be produced from the sand.

A narrow, discontinuous strip of recent dune sand exists along the shore of Lake Erie. Pit no. 1 has been developed in this material in the southeastern corner of the township. The material extracted was used primarily as blending sand for asphalt production. The Lake Erie dune sand may also be suitable for use as metal casting sand, filtration sand, and fill. Extraction for these purposes has taken place east of the township, between Port Colborne and Crystal Beach (Feenstra 1981). These deposits have not been selected for possible resource protection in the township since a large percentage of the material is currently unavailable for extractive development, because of extensive cottage development on and adjacent to the dunes.

BEDROCK GEOLOGY

Surficial material in the Township of Wainfleet is underlain by the Upper Silurian Salina and Bertie Formations as well as by the Lower to Middle Devonian Bois Blanc Formation and the Middle Devonian Onondaga Formation. Drift overlying the bedrock is generally thinnest in the southern part of the township near Lake Erie. A number of quarries have been developed in this area and bedrock is exposed in several outcrops.

The Salina Formation underlies the northern part of the township. The formation consists of argillaceous dolostone and shale with lenses of gypsum and other evaporitic materials (Telford and Tarrant 1975a, b). The formation has little value for aggregate, but has been mined for gypsum elsewhere in southern Ontario.

In the southern part of the township, an east-west trending bedrock ridge known as the Onondaga Escarpment is a prominent physiographic feature. The Escarpment was formed by differential erosion between the resistant dolostones of the Bertie Formation and the softer underlying Salina Formation. Telford and Tarrant (1975b) have described four units which make up the Bertie Formation in this area. The lowermost unit consists of 12 to 15 feet (4 to 5 m) of thick-bedded, bituminous dolostone which is overlain by 8 to 10 feet (2 to 3 m) of very argillaceous dolostone. This in turn is overlain by about 5 feet (1.5 m) of very fine-grained dolostone. The uppermost unit consists of 7 to 10 feet (2 to 3 m) of mottled brown dolostone. The formation is suitable for the production of a wide range of high- specification construction and road-building products. However, the very argillaceous dolostone section may be unsuitable for some aggregate uses because of poor durability (Hewitt 1960).

The Bertie Formation is overlain by the limestones of the Bois Blanc Formation. The Bois Blanc strata consist mainly of brownish grey, cherty, medium- to thin-bedded limestone. The formation is commonly fossiliferous and contains shale partings and minor dolostone. At the base of the formation a sandstone unit of up to 4 feet (1.2 m) thick is often present in the area (Telford and Tarrant 1975b).

The youngest bedrock which underlies the township is the Onondaga Formation. It is a medium- to massive-bedded, fine- to coarse-grained limestone. The formation is often fossiliferous and has a variable chert content. Both the Bois Blanc and Onondaga Formations have been quarried for crushed stone, but their chert content makes much of the material unsuitable for concrete aggregate. The Onondaga Formation has also been used as a raw material in cement manufacture. At quarry no. 2, high purity limestone was extracted for this purpose, but the high purity stone has been largely depleted (Hewitt 1960).

SELECTED BEDROCK RESOURCE AREAS

Three areas have been selected for possible bedrock resource protection in the Township of Wainfleet. They are located south of the village of Wainfleet near the shore of Lake Erie. The bedrock in these areas is overlain by less than 25 feet of drift and includes the Bertie, Bois Blanc and Onondaga Formations. Of these, the chert- free Bertie dolostone is considered the most desirable for extractive development as a wider range of products can be produced from the rock. The Bois Blanc Formation and part of the Onondaga Formation have been selected primarily on the basis of the availability of the underlying Bertie dolostone for extraction. The Selected Bedrock Resource Areas occupy a total available area of approximately 2600 acres (1050 ha) and contain resources of approximately 510 million tons (465 million tonnes). The selected areas are readily accessible by road and rail. The Welland Canal, a major shipping route in the Great Lakes area, is also situated nearby.

SELECTED BEDROCK RESOURCE AREA 1

Three areas, labelled 1a, 1b and 1c on Map 3, make up Selected Bedrock Resource Area 1. Less than 25 feet (8 m) of drift overlies the Bertie dolostone in this Area. No material has been extracted from the Area, however, the Bertie Formation, underlying the Bois Blanc limestone in quarry no. 1 (in Selected Bedrock Resource Area 2), has been extracted to produce a wide range of aggregate products.

Resource Area 1 occupies a total of 700 acres (285 ha), exclusive of the licenced area. Deletions for cultural constraints reduce the area currently available to 570 acres (231 ha). Assuming a workable thickness of 40 feet (12 m), available bedrock resources are estimated to total 82 million tons (74 million tonnes).

SELECTED BEDROCK RESOURCE AREA 2

Selected Bedrock Resource Area 2 is made up of Areas 2a, 2b and 2c as shown on Map 3. The bedrock in Area 2 is covered by less than 25 feet (8 m) of drift and consists of both the Bois Blanc limestone and the underlying Bertie Formation. Since the Bois Blanc strata average only 15 feet (5 m), it is possible to also extract the underlying Bertie Formation, resulting in a 55-foot (17 m) workable thickness estimate. Only one

quarry, licenced quarry no. 1, has been developed in Area 2.

Quarry no. 1, operated by R.E. Law Crushed Stone Limited, is the major producer of aggregate in the township. The total depth of the quarry is approximately 65 feet (20 m), but most extractive activity is presently concentrated in the northern part of the quarry where the total face height is 40 feet (12 m). Here, faces are worked in an upper 22-foot (7 m) and lower 18-foot (6 m) lift. The lifts expose primarily Bertie dolostone which is overlain by 7 to 8 feet (2 m) of Bois Blanc strata. Within the Bertie Formation is a 10-foot (3 m) layer of argillaceous dolostone which may be unsuitable for some aggregate uses. Towards the southwestern end of the quarry, the Bois Blanc limestone increases in thickness to about 14 feet (4 m).

A wide range of products are produced from the quarry including crushed stone for hot-laid asphalt, concrete and granular base course. Railway ballast and armour stone are also produced. The cherty limestone of the Bois Blanc Formation is used to produce a lower grade product than the rock of the Bertie Formation. The Bois Blanc limestone has been used in secondary road construction in the area. The Ontario Ministry of Transportation and Communications report that only the chert-free and shale-free material is suitable for use in hot-laid asphalt.

Selected Resource Area 2 occupies 1140 acres (460 ha), exclusive of the licenced area. An estimated 940 acres (380 ha) are currently available for extraction, containing bedrock resources of approximately 186 million tons (169 million tonnes).

SELECTED BEDROCK RESOURCE AREA 3

Selected Bedrock Resource Area 3 is made up of two areas, designated 3a and 3b on Map 3. The bedrock surface in Area 3 consists of the Onondaga limestone which is overlain by less than 25 feet (8 m) of drift. Since the Onondaga Formation thins in a northerly direction and the underlying Bois Blanc limestone averages only 15 feet (5 m) thick, it is also possible to extract part of the Bertie dolostone in the area near the Onondaga-Bois Blanc contact. For this reason, the southern boundary of Area 3b is marked by a geological thickness boundary. The boundary denotes the approximate point where the Onondaga and Bois Blanc Formations reach a combined thickness of 30 feet (9 m). North of this boundary it is considered economically viable to extract the high quality Bertie dolostone along with the overlying Onondaga and Bois Blanc strata.

The Onondaga and Bois Blanc limestones in Area 3 are generally suitable for use as granular base course and railway ballast. However, the high chert content of the rocks prevents them from being used for higher specification products. Higher quality rock, in Area 3, is available from the Bertie Formation which is suitable for higher specification products such as concrete stone.

Parts of quarry nos. 1 and 2 extend into the Resource Area. In the southwestern corner of quarry no. 1, a maximum of approximately 14 feet (4 m) of Onondaga limestone overlies the Bois Blanc and Bertie Formations. Faces in quarry no. 2 range from 10 to 15 feet (3 to 5 m) and expose very fossiliferous Onondaga limestone. High- purity limestone from this quarry has been used in the past as raw material in cement manufacture, but the majority of the high-purity material has been depleted. A number of small, long-abandoned quarries, located between quarry no. 2 and the township's eastern boundary, have also extracted high-purity limestone, but these excavations are presently water filled and have not been shown on Map 3. Further exploration is required to delineate additional resources of high-purity limestone in the Onondaga Formation.

Resource Area 3 totals 1650 acres (670 ha), exclusive of the licenced area. Cultural constraints and previous extraction reduce the area presently available to 1100 acres (445 ha). Assuming a workable thickness of 60 feet (18 m), available bedrock resources are estimated to be 238 million tons (216 million tonnes).

SUMMARY

The sand and gravel deposits of the Township of Wainfleet are the product of glacial activity which occurred during the Great Ice Age as well as the postglacial deposition of dune sand. A number of sand dunes and a beach deposit have been selected at the secondary level of significance. These deposits contain only limited resources of sand and gravel. However, the existing granular resources may be capable of meeting some of the local demands for low-specification construction products.

Since the township has a limited supply of quality sand and gravel, it relies on bedrock-derived aggregate and imported sand and gravel to meet most of its needs. Three areas in the township have been selected for possible bedrock resource protection. The bedrock in these areas consists of the Bertie, Bois Blanc and Onondaga Formations which are capable of supplying a range of aggregate products.

Enquiries regarding the Aggregate Resources Inventory for the Township of Wainfleet should be directed to the Ontario Ministry of Natural Resources, either at the Niagara District Office, Highway 20, Box 1070, Fonthill, Ontario, L0S 1E0 (Tel. (416) 892-2656) or at the Central Region Office, 10670 Yonge Street, Richmond Hill, Ontario, L4C 3C9 (Tel. (416) 884-9203).

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, TOWNSHIP OF WAINFLEET*.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
1	S-WD	90 (36)	7 (6)
2	S-WD	340 (138)	10 (9)
3	G-LB	95 (38)	2 (2)
	S-LD	5800 (2350)	116 (105)
	S-WD	165 (67)	4 (4)
4	S-LP	78 (32)	1 (1)
		6600 (2650)	140 (127)

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, TOWNSHIP OF WAINFLEET.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet Metres	8 % Gravel
UNLICENCED PITS*							
1	W3-16	Unknown	3	1			rehabilitated, dune sand

N.B. Minor variations in all tables are caused by rounding of data.

*Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, TOWNSHIP OF WAINFLEET.

1 Deposit No.	2 Unlicenced Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
			-NONE-			

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, TOWNSHIP OF WAINFLEET

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
25-50	Salina	60	40	8
(8-15)	Formation	(18)	(16)	(7)
0-3	Bertie	40	50	7
(0-1)	Formation	(12)	(20)	(6)
3-25	Bertie	40	830	120
(1-8)	Formation	(12)	(335)	(109)
25-50	Bertie	40	970	140
(8-15)	Formation	(12)	(390)	(127)
			1850	265
			(750)	(240)
0-3	Bois Blanc	15	530	29
(0-1)	Formation	(5)	(214)	(26)
3-25	Bois Blanc	15	750	40
(1-8)	Formation	(5)	(305)	(36)
25-50	Bois Blanc	15	480	26
(8-15)	Formation	(5)	(194)	(24)
			1760	95
			(710)	(86)
0-3	Onondaga	35	1510	190
(0-1)	Formation	(11)	(610)	(172)
3-25	Onondaga	35	1610	203
(1-8)	Formation	(11)	(650)	(184)
25-50	Onondaga	35	380	48
(8-15)	Formation	(11)	(154)	(44)
			3500	440
			(1420)	(400)
			7200	810
			(2900)	(740)

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 5. QUARRIES, TOWNSHIP OF WAINFLEET.

1 NO.	2 MTC NO.	3 OWNER/ OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
LICENCED QUARRIES						
1	W3-2	R.E. Law Crushed Stone Ltd.	3,4,5	2	253.0 (102.4)	40-65 (12-20)
UNLICENCED QUARRIES*						
2	W3-1	Niagara Peninsula Conservation Authority	5,6	1		10-15 (3-5) partially water filled

N.B. Minor variations in all tables are caused by rounding of data.

*Abandoned quarries or wayside quarries operating on demand under authority of a permit.

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, TOWNSHIP OF WAINFLEET.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
1a	3-25	350	80	0	270	40	39
	(1-8)	(142)	(32)	(0)	(109)	(12)	(35)
1b	3-25	85	25	0	60	40	9
	(1-8)	(34)	(10)	(0)	(24)	(12)	(8)
1c	0-25	270	30	0	240	40	34
	(0-8)	(109)	(12)	(0)	(97)	(12)	(31)
		700	135	0	570		82
		(285)	(55)	(0)	(231)		(74)
2a	0-25	340	60	0	280	55*	55
	(0-8)	(138)	(24)	(0)	(113)	(17)	(50)
2b	3-25	310	60	0	250	55*	50
	(1-8)	(125)	(24)	(0)	(101)	(17)	(45)
2c	0-25	490	80	0	410	55*	81
	(0-8)	(198)	(32)	(0)	(166)	(17)	(73)
		1140	200	0	940		186
		(460)	(81)	(0)	(380)		(169)
3a	0-25	220	160	0	60	60**	13
	(0-8)	(89)	(65)	(0)	(24)	(18)	(12)
3b	0-25	1430	370	20	1040	60**	225
	(0-8)	(580)	(150)	(8)	(420)	(18)	(204)
		1650	530	20	1100		238
		(670)	(214)	(8)	(445)		(216)
		3500	860	20	2600		510
		(1420)	(350)	(8)	(1050)		(465)

N.B. Minor variations in all tables are caused by rounding of data.

*Workable thickness estimate in Area 2 includes both the Bois Blanc Formation and the underlying Bertie Formation.
**Workable thickness estimate in Area 3 includes the Onondaga and Bois Blanc Formations along with part of the underlying Bertie formation.

TABLE 7. SUMMARY OF TEST HOLE DATA, TOWNSHIP OF WAINFLEET.

-NONE-

N.B. Minor variations in all tables are caused by rounding of data.

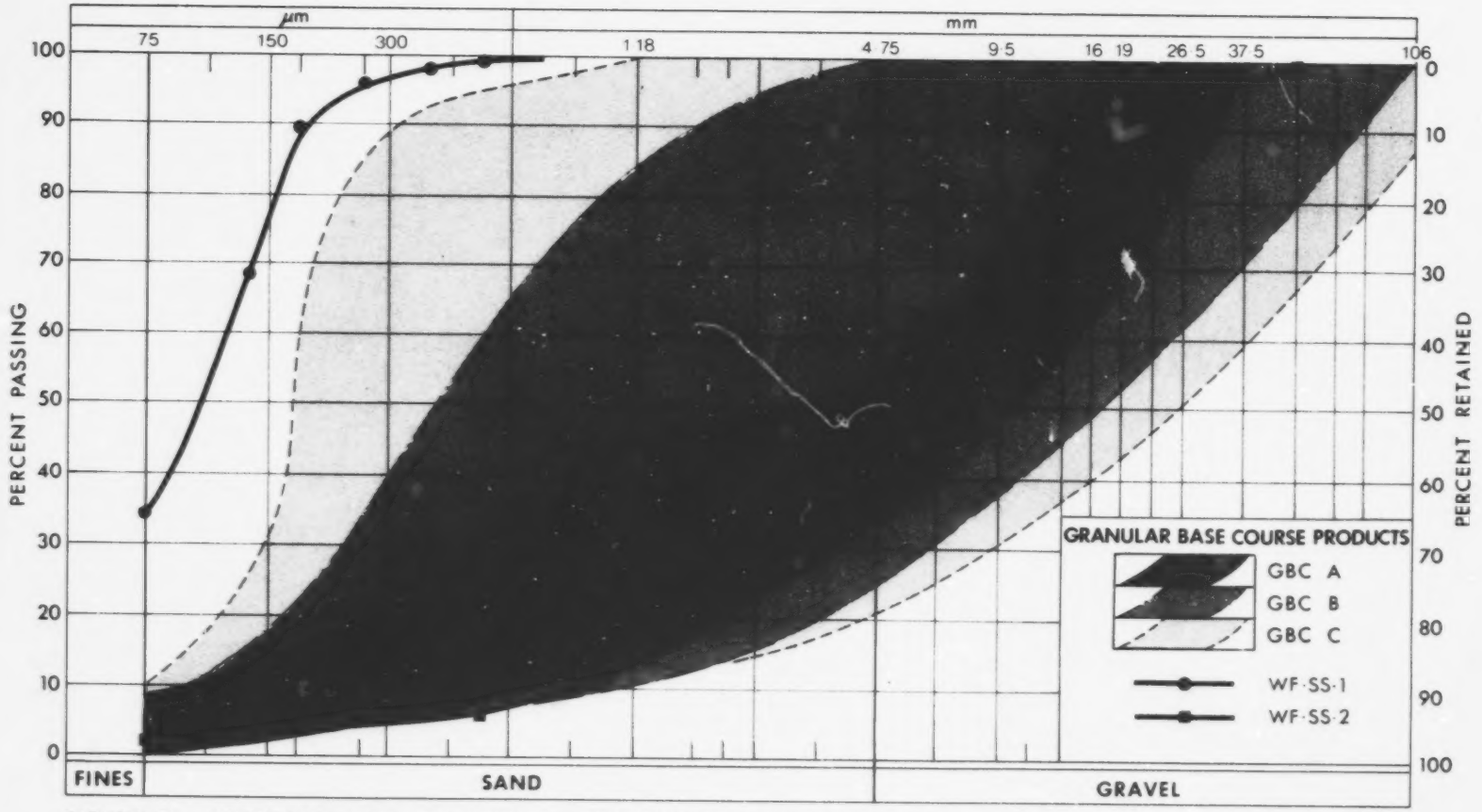


FIGURE 2: AGGREGATE GRADING CURVES, TOWNSHIP OF WAINFLEET (after Feenstra, 1981)

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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Appendix A — Suggested Additional Reading

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Cambrian: The first period of the Palezoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic Era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuties. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near- ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

Bass Islands Formation (Upper Silurian)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18 m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunnville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate because of high soundness losses.

Bobcaygeon Formation (Middle Ordovician)

Composition: Compact, homogeneous, medium- to thin-bedded, fine- grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

Bois Blanc Formation (Lower-Middle Devonian)

Composition: Brownish grey, medium-crystalline, medium- to thin- bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High cherty content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

Dundee Formation (Middle Devonian)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys as raw material for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

Gull River Formation (Middle Ordovician)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

Lockport and Amabel Formations (Middle Silurian)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive- bedded, fine-to medium-grained dolostone. Thickness: Amabel Formation: maximum observed

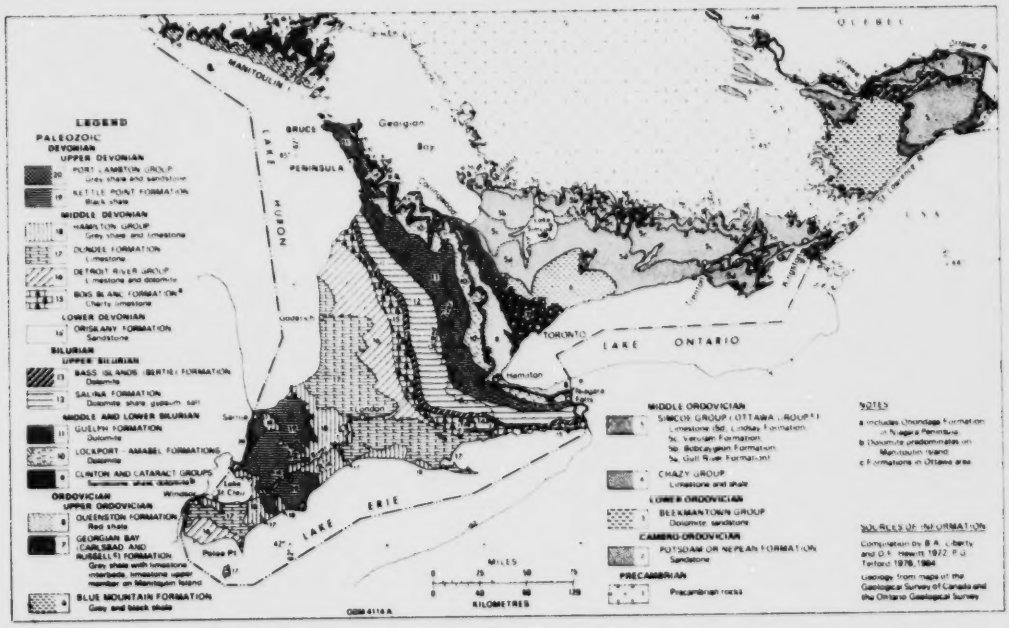


Figure 3. Bedrock Geology of Southern Ontario.

thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

Onondaga Formation (Middle Devonian)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium- grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey- brown, fine-grained, very cherty limestone having estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey-brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High cherty content makes much of the material unsuitable for concrete aggregate.

Ottawa Formation (Middle Ordovician)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of limestone for cement production and agricultural uses.

Oxford Formation (Lower Ordovician)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

Detroit River Group (Middle Devonian)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces much of Ontario's lime and cement. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

Grenville Marble (Precambrian)

Composition: Recrystallized fine- to coarse-grained white limestone and dolostone, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

Guelph Formation (Middle Silurian)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. Thickness: 100 to 170 feet (30 to 52 m). Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

Lindsay Formation (Upper Ordovician)

Composition: fine-crystalline, rubbly, nodular-weathering limestone. Collingwood Member: organic-rich interbedded calcareous shales and limestones. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

Verulam Formation (Middle Ordovician)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for use in cement manufacture. The formation is unsuitable for crushed stone because of clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

Georgian Bay Formation (Upper Ordovician) (Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue-grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in the vicinity of Metro Toronto produce brick and structural tile. Lightweight aggregate has been produced at Streetsville by heat expansion of the shale.

Hamilton Group (Middle Devonian)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona Formation is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). The Arkona Formation has a thickness of 14 to 121 feet (4 to 37 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile.

Queenston Formation (Upper Ordovician)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

Nepean (Potsdam) Formation (Cambro-Ordovician)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

Salina Formation (Upper Silurian)

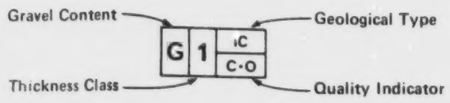
Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

Blue Mountain Formation (Upper Ordovician)

(Formerly known as the Whitby Formation) Composition: Blue-grey, predominantly non-calcareous shale. Uses: Quarried at Bowmanville for use in cement production.

(Continued from right margin)

DEPOSIT SYMBOL



Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e. material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per acre. Geological Type refers to geologic origin. Quality Indicator describes objectionable grain size and lithology.

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.

Thickness Class

Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (> 112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10 (1.5-3)	12,500 - 25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12, 500 (< 28 000)

Geological Type

AL	Older Alluvium	**K**	Kame
E	Esker	**LB**	Lacustrine Beach
EM	End Moraine	**LD**	Lacustrine Delta
IC	Undifferentiated Ice-Contact Stratified Drift	**LP**	Lacustrine Plain
		OW	Outwash
ICT	Ice-Contact Terrace	**WD**	Windblown Forms

(see Appendix C for descriptions of Geological Types)

Quality Indicator

	If blank, no known limitations present.
C	Clay and/or silt (fines) present in objectionable quantities.
L	Deleterious lithologies present.
O	Oversize particles or fragments present in objectionable quantities.

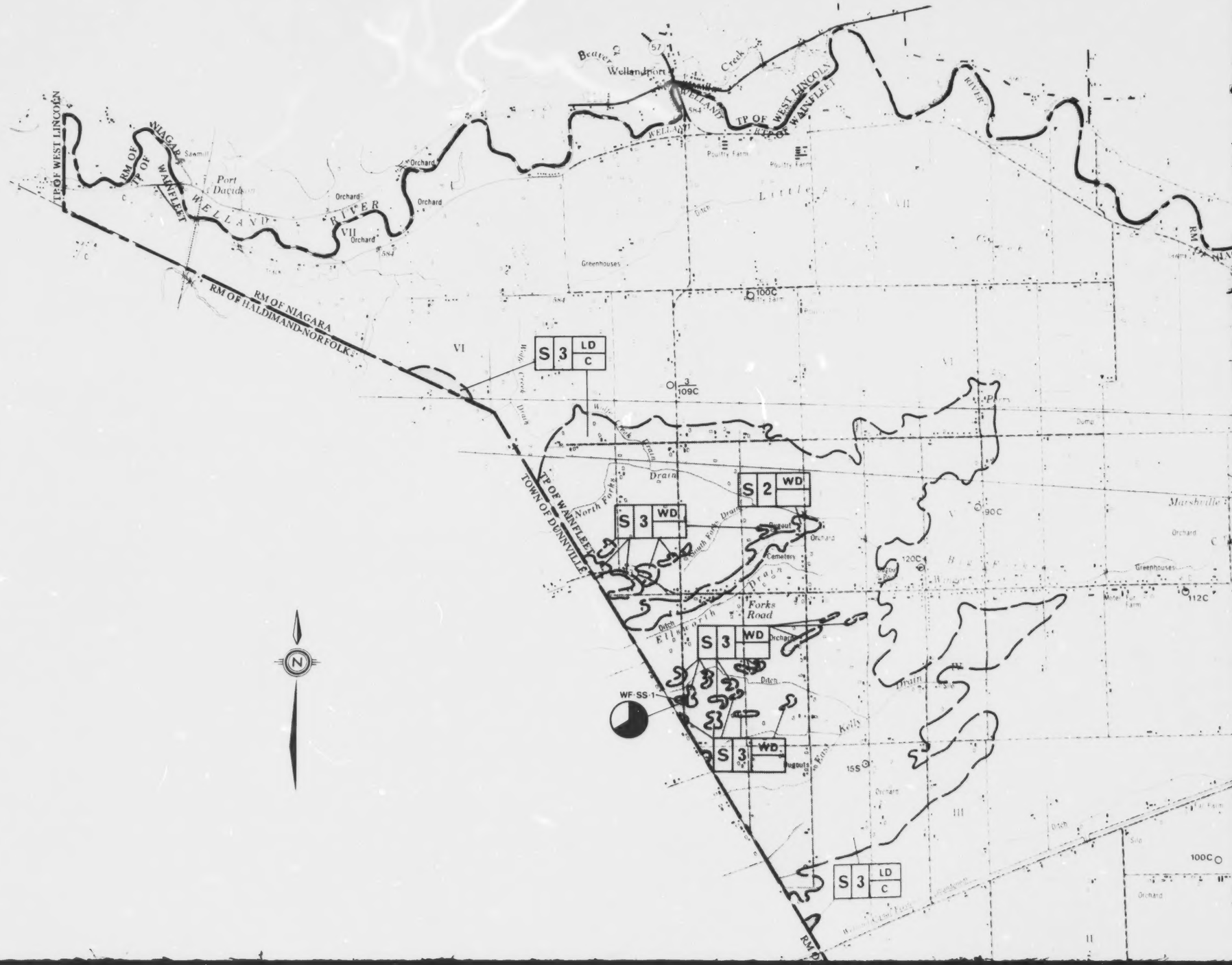
TEXTURE SYMBOL

(This symbol is used where sample analysis data are available.)

The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.



Ministry of Natural Resources

Ontario

Hon. Michael Harris
Minister

Mary Mogford
Deputy Minister

ONTARIO GEOLOGICAL SURVEY

AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF WAINFLEET

REGIONAL MUNICIPALITY OF NIAGARA

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 30 L/13, 30 L/14
30 M/3, 30 M/4

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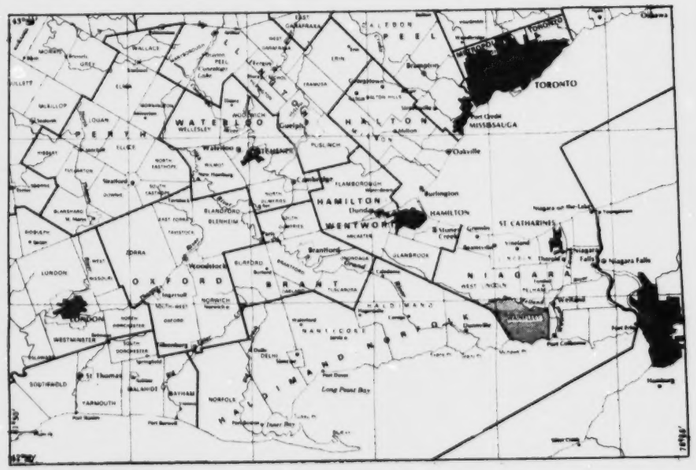

SYMBOLS

(Some symbols may not apply to this map.)

Geological and aggregate thickness boundary. Shading indicates deposit area.

Buried geological and aggregate thickness boundary. Shading indicates deposit area.

Municipal boundary.

3	5-10 (1.5-3)	12,500 - 25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12, 500 (< 28 000)

Geological Type

AL	Older Alluvium	**K**	Kame
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ICT	Ice-Contact Terrace	**OW**	Outwash
		WD	Windblown Forms

(see Appendix C for descriptions of Geological Types)

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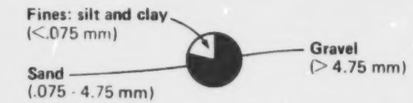

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SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Test hole data from Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Natural Resources.
Selected drilled water well data from the Ontario Ministry of the Environment.
Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: B.H. Feenstra, 1972, 1974.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

This map is to accompany O.G.S. Aggregate Resources Inventory Paper 115.

This map is published with the permission of V. G. Milne, Director, Ontario Geological Survey.
Issued 1985.

Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.

NTS Reference: 30 L/13, 30 L/14
30 M/3, 30 M/4

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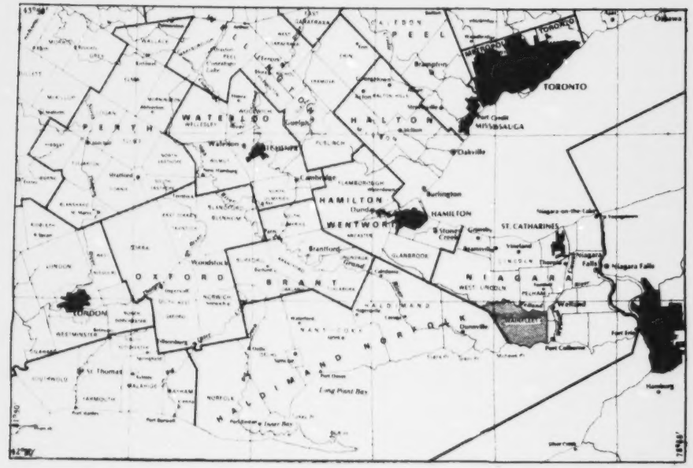

SYMBOLS

(Some symbols may not apply to this map.)

Geological and aggregate thickness boundary. Shading indicates deposit area.

Buried geological and aggregate thickness boundary. Shading indicates deposit area.

Municipal boundary.

2 — Licenced property boundary; Property number: see Table 2.

● 3 — Unlicenced sand or gravel pit*; Property number: see Table 2.
*Abandoned pit or wayside pit operating on demand under authority of a permit.

WF-TH-2 — Selected test hole location; Identification number.

○ 6/23 G — Selected drilled water well location; reported thickness of material (in feet); reported type of material (number only - overburden, T - till, G - gravel, S - sand, C - clay, Bk - bedrock).

G 1 IC C-O — Deposit Symbol: see left margin.

Texture symbol: see left margin.

■ WF-SS-2 — Selected sample site; Identffication number: see Figure 2.

(Continued at left margin)

WAINFLEET

TP OF WEST LINCOLN
RM OF NIAGARA
TP OF WAINFLEET
WELLAND
Port Dalhousie
Sawmill
Orchard
RIVER
Track
RM OF HALDIMAND-NORFOLK
TP OF WAINFLEET
TOWN OF DUNNVILLE
Bradley's Creek
Wellandport
Creek
WELLAND
TP OF WEST LINCOLN
TP OF WAINFLEET
RIVER
Poultry Farm
Little Forks
Ditch
Greenhouses
VII
VI
V
IV
III
II
Willick Creek Drain
North Forks Drain
South Forks Drain
Cemetery
Dugouts
Big Forks
Winger
Forks Road
Ellsworth Drain
Kelly
Bank
Welland Canal Feeder (abandoned)
Perry
Dump
Silo
Golf Course
Dugout
Bucketts Bridge
Marshville
Sports Track Reservoir
Chambers' Corners
Control Valve
Motel
Fur Farm
Wainfleet
Gas Pipeline
Underground
CANADIAN NATIONAL
Orchards

Ministry of Natural Resources

Ontario

Hon Michael Harris
Minister

Mary Mogford
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF WAINFLEET

REGIONAL MUNICIPALITY OF NIAGARA

MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 30 L/13, 30 L/14
30 M/3, 30 M/4

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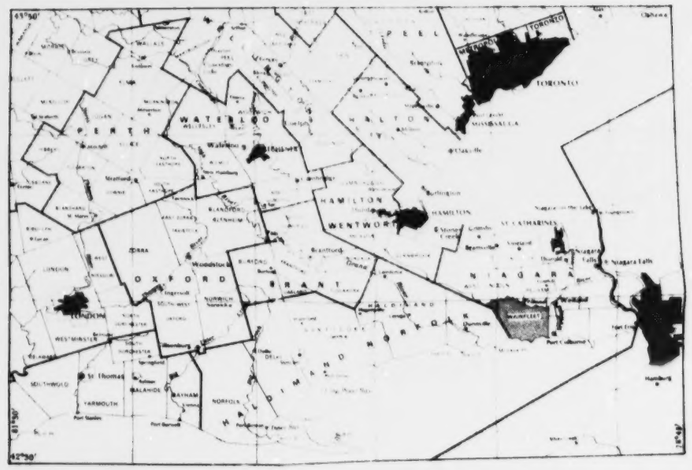

SYMBOLS

(Some symbols may not apply to this map.)

— — — — Geological and aggregate thickness boundary.

•••••••••••••••••• Buried geological and aggregate thickness boundary.

——— — ——— Municipal boundary.

Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.

TOWN OF DUNNVILLE
TP OF WAINFLEET
RM OF NIAGARA
RM OF HALDIMAND
NORFOLK
WELLAND
Beckett's Bridge
Marshville
CANADIAN NATIONAL
Big Forks
Winger
Forks Road
Ellsworth
Kelly
Wainfleet
Chambers' Corners
Golf Course
Cemetery
Orchard
Dugouts
Ditch
Drain
Willow Bay
Long Beach
Burnaby
Morgans Point
LAKE

significance; Deposit number: see Table 3.

Metres 1000 0 1 Kilometre

NTS Reference: 30 L/13, 30 L/14
30 M/3, 30 M/4

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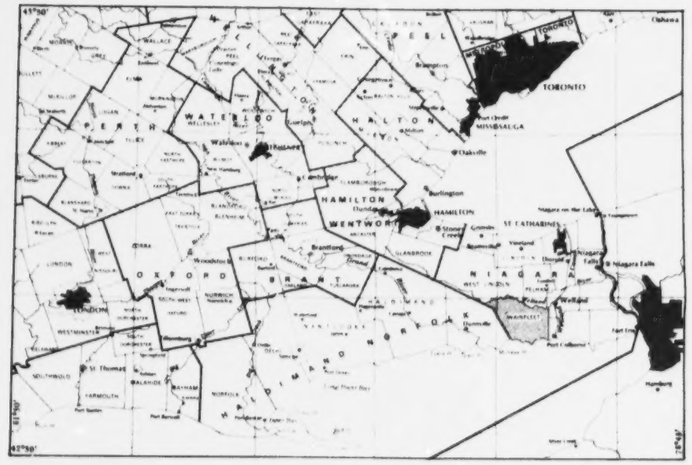

SYMBOLS

(Some symbols may not apply to this map.)

- Geological and aggregate thickness boundary.
- Buried geological and aggregate thickness boundary.
- Municipal boundary.
- Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area; Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
- 2 — Licenced property boundary; Property number: see Table 2.
- 3 — Unlicenced sand or gravel pit*; Property number: see Table 2.
  *Abandoned pit or wayside pit operating on demand under authority of a permit.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Geology by: B.H. Feenstra, 1972, 1974.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

This map is to accompany O.G.S. Aggregate Resources Inventory Paper 115.

This map is published with the permission of V. G. Milne, Director, Ontario Geological Survey.

Issued 1985.

WAINFLEET

TP OF WEST LINCOLN
RM OF NIAGARA
TP OF WAINFLEET
WELLAND
RIVER
Port Dalhousie
Beaverdams
Wellandport
Creek
TP OF WEST LINCOLN
TP OF WAINFLEET
Poultry Farm
Little Forks Ditch
Greenhouses
Golf Course
RM OF NIAGARA
Beckett's Bridge
TOWN OF PELHAM
TP OF WAINFLEET
RM OF NIAGARA
RM OF HALDIMAND-NORFOLK
SALINA FORMATION
CONRAIL
CANADIAN NATIONAL
Marshville
Creek
Chambers Corners
Forks Road
Big Forks Ditch
Winger
Dump
Perry
Ditch
Drain
North Forks Drain
South Forks Drain
Ellsworth Drain
Kelly Drain
East Dugouts
Cemetery
Orchard
Sports Track
Reservoir
Motel
Fur Farm
Waterfleet
Gas Pipeline
underground
Welland Canal Feeder
Abandoned
Orchards
TP OF WAINFLEET
TOWN OF DUNNVILLE
RM OF NIAGARA
SALINA FORMATION
VI
VII
V
IV
III
II
80
106
107
120
127
113
166
N

Ministry of Natural Resources

Ontario

Hon. Michael Harris
Minister

Mary Mogford
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF WAINFLEET
REGIONAL MUNICIPALITY OF NIAGARA

MAP 3
BEDROCK RESOURCES

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 30 L/13, 30 L/14
30 M/3, 30 M/4

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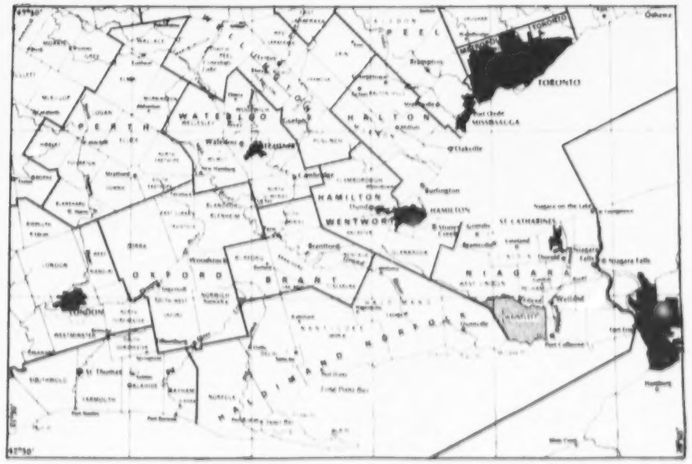


LEGEND

PALEOZOIC

DEVONIAN

MIDDLE DEVONIAN

ONONDAGA FORMATION
Cherty limestone

LOWER TO MIDDLE DEVONIAN

BOIS BLANC FORMATION
Cherty limestone

SILURIAN

UPPER SILURIAN

BERTIE FORMATION
Dolostone

SYMBOLS

(Some symbols may not apply to this map.)

Geological formation boundary.

Geological formation member boundary.

Formation thickness boundary (see text).

25 — Drift thickness contour: 25-foot (8 m) interval.

Municipal boundary.

2 — Selected bedrock resource area; Deposit number: see Table 6.

Bedrock exposed or near surface; covered by less than 3 feet (1 m) of overburden: see Table 4.

SALINA FORMATION

TP OF WAINFLEET
TOWN OF DUNNVILLE

Drain
North Fork Drain
South Fork Drain
Dugout
Orchard
Cemetery
Forks Road
Ditch
Ellis Creek
Poultry Farm
Big Forks
Winger
Greenhouse
Marshville
Creek
Chambers Curtis
Motel
Fur Farm
Kelly
East Kelly Drain
Dugouts
Silo
Ditch
Wainfleet
Welland Canal Feeder
Cabbageworld
Orchards
Sports Field
Reservoir
Golf Course
TP OF PELHAM
TP OF WAINFLEET
WELLAND
CONRAIL
CANADIAN NATIONAL
Fur Farm
Dump
Perry

RM OF HALDIMAND-NORFOLK
RM OF NIAGARA

SALINA FORMATION

BERTIE FORMATION

BOIS BLANC FORMATION

FORMATION

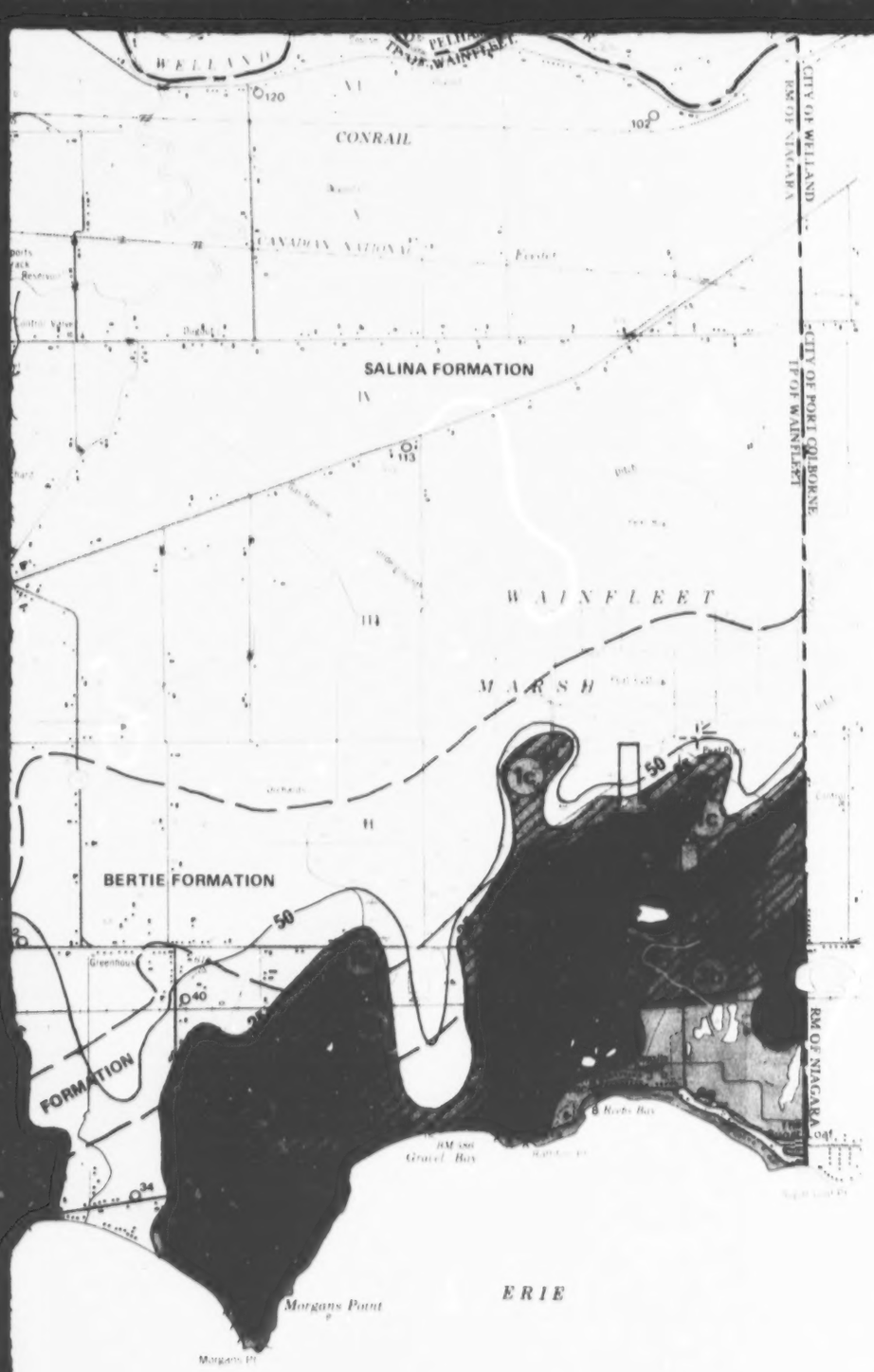
50

Willow Bay
Long Beach
Morgans Point
Gravel Bay
BM 580
Morgans Pt
Rock Pt
Grabel Pt

LAKE ER

VI
V
IV
III
II
I

120
127
113
166
123
43
42
40
34
20



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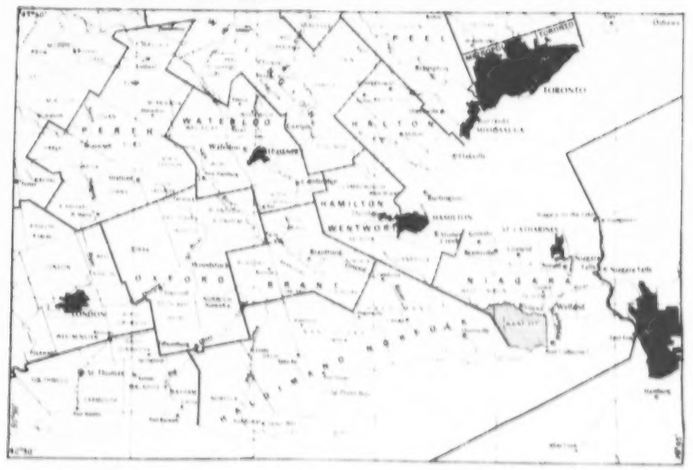

LEGEND

PALEOZOIC

DEVONIAN

MIDDLE DEVONIAN

ONONDAGA FORMATION
Cherty limestone

LOWER TO MIDDLE DEVONIAN

BOIS BLANC FORMATION
Cherty limestone

SILURIAN

UPPER SILURIAN

BERTIE FORMATION
Dolostone

SALINA FORMATION
Dolostone, shale, gypsum, salt

SYMBOLS

(Some symbols may not apply to this map.)

- Geological formation boundary.
- Geological formation member boundary.
- Formation thickness boundary (see text).
- 25 — Drift thickness contour: 25-foot (8 m) interval.
- Municipal boundary.
- 2 — Selected bedrock resource area. Deposit number: see Table 6.
- Bedrock exposed or near surface; covered by less than 3 feet (1 m) of overburden: see Table 4.
- Bedrock covered by 3 to 25 feet (1 to 8 m) of overburden: see Table 4.
- Bedrock covered by 25 to 50 feet (8 to 15 m) of overburden: see Table 4.
- X — Isolated bedrock outcrop.
- Q2 — Licenced quarry boundary. Property number: see Table 5.
- Q3 — Unlicenced quarry*. Property number: see Table 5. *Abandoned quarry or wayside quarry operating on demand under authority of a permit.
- 28 — Selected drilled waterwell location; reported depth to bedrock (in feet).

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Selected drilled water well data from the Ontario Ministry of the Environment.

Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: B.H. Feenstra, in preparation.
B.H. Feenstra and M. Troper, 1982.
P.G. Telford and G.A. Tarrant, 1975 a, b.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

This map is to accompany O.G.S. Aggregate Resources Inventory Paper 115.

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